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ABSTRACT

The issue of whether English second language (ESL) instruction and mathematics instruction can be effectively integrated with each other in the elementary grades is discussed, and it is suggested that contrary to popular belief, mathematics has great potential for second language development. It is noted that the input hypothesis of language learning supports integration of language and subject matter, because content classes provide children with meaningful and interesting language input. Certain conditions are seen as essential for effective integration of mathematics and ESL at the elementary level, including careful development of mathematical terminology and related language, an activity-centered approach to learning, and a classroom environment that fosters communication among students. Eight integrated mathematics/ESL activities for grades 1-4 are included. (Contains 39 references.) (MSE)

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INTEGRATING ENGLISH AS A SECOND LANGUAGE AND MATHEMATICS INSTRUCTION IN THE ELEMENTARY GRADES

by

Barbara Allen

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Abstract

The paper investigates the question of whether English as a second language and mathematics instruction can be integrated successfully in the elementary school years. The need for content-based language instruction arose in the United States when schools attempted to provide a growing number of limited English proficient students with equal educational opportunities, but the concept of teaching English through relevant subject matter is also of interest in situations in which English is taught as a foreign language. On the theoretical level, the integration of language and subject matter is supported by Krashen's Input Hypothesis. Krashen points out that content classes such as mathematics provide naturally meaningful and interesting language input for the school child. The paper posits that an integration of mathematics and English as a second language at the elementary level can be beneficial if certain conditions are met. These include careful development of mathematical terminology as well as related language, an activity-centered approach to learning, and a classroom environment which fosters communication among students. The paper concludes by

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outlining eight integrated mathematics/ESL activities for grades one through four.

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Although much of traditional second language teaching focused on the study of language per se, content instruction has always been important to some degree. As Mohan (1986, p. 3) points out: "Even in the traditional Latin class, students often learned about Roman civilization, and learned Latin in the process of doing so." Especially at the more advanced stages of second language teaching, the history, culture, and literature associated with the target language have traditionally been given due consideration. Thus, content-based second language instruction has always been practiced to some extent. In recent years, however, the concept has been looked at and interpreted much more rigorously. According to Short (1989), content-based language instruction is currently defined as an

> approach that integrates second language instruction with subject matter instruction. Each lesson in a content-based class has content objectives (e.g., math, science, social studies) and language objectives (e.g., grammar, functions). Students learn language through the

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> context of specific subject matter rather than through isolated language features. (p. 1)

Thus, in content-based language instruction the main topics taught come from the regular school curriculum (Curtain & Martinez, 1989). The key difference between earlier approaches to second language teaching and the current emphasis on content-based instruction is the realization that subject and language learning go hand in hand. In a content-based approach, language learning is carefully coordinated and integrated with other curricular areas. Cooperation between second language teachers and content teachers is essential.

The major driving force behind the development of content-based language instruction in the United States has been the sheer necessity of providing equal educational opportunities for a steadily growing number of language-minority school-aged children. According to estimates by Chapa (1990) limited English proficient (LEP) children represented 8 percent of the total school-age population (ages 5-17) in the United States in 1988. By comparison, in 1979 this figure was 5 percent. It should be added that this percentage is

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much higher in states with sizable immigrant populations, such as California, New York, and Texas.

In the past, language-minority children were often simply placed in regular classrooms, receiving perhaps some special instruction in English in a separate class. This approach assumed that students would learn English simply by being exposed to it in their school environment as well as in the English-speaking community. However, educators soon realized that these students fell behind in their academic subjects. Mohan (1986, p.7) notes that recent "research on language and learning in the content class suggests that we need more than a laissez-faire approach to help students with the language demands of the content class."

This paper will investigate the possibility of integrating the teaching of mathematics and English as a second language. Mathematics has traditionally not been considered a subject suitable for fostering second language acquisition. The paper will demonstrate that, contrary to this belief, mathematics, especially in the early grades, has great potential for language development. Mathematics teaches problem-solving skills. Problem-solving skills can in turn be learned in interesting group activities which foster

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communication and thereby language development. It is argued in this paper that mathematics can promote second language acquisition if an activity-centered teaching approach is taken, and if specialized mathematics vocabulary as well as basic vocabulary needed for everyday conversation are carefully developed.

Second Language Acquisition Theories

On the theoretical level, the movement to integrate language and content learning found a convincing rationale in Krashen's ideas, especially in his Input Hypothesis. Krashen (1985) posits his Input Hypothesis as the central part of a theory of second language acquisition which consists of a total of five hypotheses:

1. The Acquisition-Learning Hypothesis states that there are two independent ways of developing second language competence. One is through acquisition, a subconscious process similar to first language acquisition; the other through learning, a conscious process.

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2. The Natural Order Hypothesis states that the rules of language are acquired in a predictable, natural order, independent of the order in which rules are taught in language classes.
3. The Monitor Hypothesis is concerned with the interrelationship between acquisition and learning in producing language. Krashen claims that the ability to produce language is a result of acquired (subconscious) competence. Learning (conscious knowledge) can merely be used as an editor or a monitor to correct or change language output.
4. The Input Hypothesis posits that people acquire language by receiving 'comprehensible input.' Humans progress from one level of language acquisition to the next by receiving messages that are slightly beyond their current level of competence. If _i_ is the current level of competence, then humans move to the next level, _i_ + 1, by understanding input containing _i_ + 1 structures. It is possible to understand _i_ + 1 input with the help of context which includes extra-linguistic information, knowledge of the

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world, and previously acquired linguistic competence.

5. The Affective Filter Hypothesis states that the language acquirer needs to be open to input. The affective filter is a mental block that can prevent language acquisition. Krashen claims that the affective filter is lowest when language acquirers are actively involved in trying to get a message across, thereby forgetting that they are using a second language.

There is considerable controversy regarding Krashen's distinction between language acquisition and learning, as it certainly seems possible for learned knowledge to become subconscious through practice. His Input Hypothesis, however, continues to enjoy much support. It is important to note that simple exposure to a second language will not necessarily result in acquisition. For acquisition to take place, a sufficient amount of the language the learner is exposed to must be comprehensible, and the learner's affective filter must be lowered in order to absorb the input given. According to Krashen (1982), optimal input must be comprehensible, interesting or relevant,

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not grammatically sequenced, and of sufficient quantity. Krashen (1985) argues that for the school child, content classes such as mathematics, science, and social studies deliver naturally meaningful, interesting language input. He cites the success of certain immersion and bilingual programs in support of this statement.

Since the distinction between acquisition and learning is fuzzy, the two terms will be used interchangeably in the remainder of this paper.

Another important concept in current thinking about second language acquisition is that language is learned and used to fulfill communicative needs (Krashen & Terrell, 1983). Working from this principle, Krashen and Terrell developed the Natural Approach to second language teaching and learning. The goal of the Natural Approach is the development of basic communication skills. It is based on the following principles: (a) comprehension precedes language production; (b) production emerges gradually; and (c) activities that foster acquisition and lower the affective filter are of crucial importance. The Natural Approach centers around situations, functions, and topics using activities that foster communication.

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For example, a topic could be money and prices, and a situation would be shopping for groceries. In the Natural Approach it is important that the topics and situations chosen relate to the personal experiences of the students. Useful teaching techniques include Total Physical Response, affective-humanistic activities (dialogs, preference rankings, interviews, etc.), problem-solving activities (including charts, graphs, and maps), games, and content activities.

Cummins (1980) distinguishes between basic interpersonal communicative skills (BICS) and cognitive/academic language proficiency (CALP). Cummins argues that BICS and CALP are independent competencies. His research indicates that language-minority children often become quite competent in BICS, while lagging behind considerably in CALP compared to language-majority students. Cummins (1979, 19 4) developed two hypotheses to account for this phenomenon: the Threshold Hypothesis and the Developmental Interdependence Hypothesis.

The Threshold Hypothesis is based on the concept of balanced bilingualism. Cummins distinguishes between subtractive bilingualism (the original language of the child is gradually being replaced by a dominant

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and usually more prestigious second language) and additive bilingualism (the original language continues to be strong and is in no danger of being replaced by the second language). In the latter case another socially relevant language is added at no cost to proficiency in the dominant, prestigious first language. Balanced bilinguals have similar, high competence in the first and second language as a result of an additive bilingual environment. According to Cummins, such individuals often outperform monolinguals on cognitive tasks.

On the other hand, individuals functioning in a subtractive bilingual environment are likely to develop reduced competence in their first as well as in their second language and tend to experience difficulties on cognitive tasks compared to monolinguals (within the same age group). This suggests that there is a relationship between the levels of proficiency in the first and second language and the cognitive and academic development of the bilingual child. Cummins (1979) posits a Threshold Hypothesis which assumes

> that those aspects of bilingualism which might positively influence cognitive growth are unlikely

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> to come into effect until the child has attained a certain minimum or threshold level of competence in a second language. Similarly, if a bilingual child attains only a very low level of competence in the second (or first) language, interaction with the environment through that language, both in terms of input and output, is likely to be impoverished... The attainment of a lower threshold level of bilingual competence would be sufficient to avoid any negative cognitive effects; but the attainment of a second, higher, level of bilingual competence might be necessary to lead to accelerated cognitive growth. (pp. 229-230)

Cummins' second hypothesis, the Developmental Interdependence Hypothesis, suggests that the bilingual child's level of competence in the second language is in part dependent on his or her level of proficiency in the first language.

> The developmental interdependence hypothesis proposes that the level of L2 competence which a bilingual child attains is partially a function of

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> the type of competence the child has developed in L1 at the time when intensive exposure to L2 begins. When the usage of certain functions of language and the development of L1 vocabulary and concepts are strongly promoted by the child's linguistic environment outside of school..., then intensive exposure to L2 is likely to result in high levels of L2 competence at no cost to L1 competence. The initially high level of L1 development makes possible the development of similar levels of competence of L2. However, for children whose L1 skills are less developed in certain respects, intensive exposure to L2 in the initial grades is likely to impede the continued development of L1. This will, in turn, exert a limiting effect on the development of L2. (p. 233)

The Developmental Interdependence Hypothesis suggests that cognitive skills acquired in the first language will be transferred to the second language.

Cummins' ideas are crucial to the development of school programs for language-minority and bilingual children. Cognitive development will be optimal if and

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only if academic subject instruction is given both in the first and the second language. The total replacement of the child's first language with a second language will often result in delayed cognitive and academic development. It is thus important for the child to have the opportunity to continue to develop his or her first language. While subject instruction in two languages is possible in bilingual programs, it is, however, impractical in those situations in which several different first languages are represented in the student population.

Whereas Krashen and Terrell's Natural Approach is especially suited to develop basic interpersonal communicative skills, Cummins' hypotheses suggest that it is equally important to develop students' cognitive and academic skills. Mathematics appears to be a suitable subject for developing important cognitive skills such as deductive reasoning and problem solving skills.

Approaches to Integrating Second Language and Content Instruction

Mohan (1986) presents a convincing reason for content-based second language instruction:

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> Language learning in the communicative environment of the content classroom furthers the goals of language teaching by offering a context of communication about important subject matter. Language ceases to be taught in isolation. (p. 18)

Krashen (1985) favors integrated content and second language instruction, as it can provide students with comprehensible input that is meaningful and important to them. He proposes a four-stage model of second language development.

Stage I consists of general language teaching which lays the groundwork for basic comprehension and the early stages of second language production.

During Stage II, students are exposed to sheltered language teaching which takes place in immersion-style subject-matter classes. At this stage students learn authentic subject matter with special emphasis on further development of the second language.

During Stage III, students participate partially in mainstream classes; that is, they attend selected subject classes together with native speakers of their second language, but continue to receive instruction in some subject areas in their own native language.

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Stage IV consists of full mainstream instruction. Students now attend all subject classes in the mainstream. They might also have an enrichment class in their first language.

Krashen (1985, p. 80) proposes the following school program for limited English proficient school children attending North American public schools:

Stage	Mainstream	Sheltered	First Language
I	Art, Music, PE	ESL	All Core Subjects
II	Art, Music, PE	ESL, Math	Soc.Studies Lang. Arts
II-III	Art, Music, PE, Math	ESL, Social Studies	Enrichment
IV	All Courses		Enrichment

This model is obviously more suited to elementary education than to junior high or high school teaching. Science is missing in the table, but could be handled like social studies, although Krashen (1991) deals with it as he does with mathematics. It should be noted that in this model mathematics is the first academic subject that is taken as a sheltered class in Stage II and as a mainstream class in Stage III. Krashen (1985, p. 82) comments that "subjects such as mathematics are

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introduced in English first, since they do not require as high a level of language proficiency as subjects such as social studies or language arts." It should also be noted that the enrichment component in this model serves a very important function. It gives students the opportunity to continue to develop their first language; thus they are becoming more advanced bilinguals. As discussed earlier in this paper, balanced bilingualism enhances cognitive development.

Krashen's model could also be adapted to bilingual programs. At Stage IV the subject courses should be taught in both languages, although not simultaneously. For example, one year certain subjects could be taught in L1, with enrichment activities for these subjects in L2, and then the next year those subjects could be taught in L2, with enrichment activities in L1, while the remainder of the subjects would be taught in L1. This rotating schedule would ensure that students would continue to build their subject-language knowledge in both languages.

Krashen (1985) also developed a model for teaching a foreign language in the elementary school. The program consists of three stages: Stage I uses general language teaching, Stage II sheltered subject matter

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teaching, and Stage III partial mainstream. It should be noted that Stage III is usually not possible in the case of teaching a foreign language, except in bilingual countries. However, even Stage II offers an exciting expansion of the usual foreign language program by teaching some subject matter in the foreign language. Mathematics appears to be a very suitable subject for such enrichment activities in the foreign language, especially if the foreign language is English. The acquisition of solid mathematical, technical, and scientific English vocabulary is a definite advantage to any individual, since most of the world's technical and scientific literature is written in English. In such programs, however, subject teaching in the foreign language should be confined to enrichment or practice activities. New subject matter should be introduced in the students' native language.

Curtain and Pesola (1988) outline five different model programs for teaching a foreign language at the elementary level: total immersion, in which most of the class time is spent on learning subject matter taught in the foreign language; partial immersion, in which about half of the class time is spent on learning subject matter taught in the foreign language; content-

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enriched FLES (Foreign Language in the Elementary School), in which some of the class time is spent on learning the foreign language per se as well as on learning some subject matter in the foreign language; FLES, in which a small amount of the class time is spent on learning the foreign language per se; and FLEX (Foreign Language Exploratory Program), in which a minimal amount of the class time is spent on learning the foreign language and/or learning about the foreign language.

Content-based foreign language instruction at the elementary level is a relatively new concept which has not yet been widely applied. Nevertheless, some experimental programs have been developed. Anderson (1989) has put together a content-based curriculum for teaching French at the elementary school. The program centers around common themes, such as numbers, animals, or the weather, and develops language and content skills (mathematics, science, social studies) at the same time in each unit by using appropriate activities. Her approach is a totally integrated one which could easily be adapted to teaching English as a foreign language at the elementary level.

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To cite another example, Fischer (1991) reported in the German newspaper Frankfurter Rundschau that selected German elementary schools have begun teaching English in third grade, rather than in fifth grade as has been customary. The long-range plan calls for making this earlier starting point obligatory and for providing some subject instruction in English.

Content-based second language instruction takes thoughtful preparation to make it work successfully. Content teaching in and of itself does not necessarily foster language development. Swain (1988, p. 68) warns that "not all content teaching is necessarily good language teaching." She observed many language classes and found that their focus is generally meaning- rather than language-oriented. In such classes the students usually have little opportunity to speak, as only short answers are required. Swain goes on to suggest that systematic integration of content and second language teaching is needed if the students' understanding of form-meaning relationships is to be facilitated. Special attention has to be devoted to the language development component. The teacher also has to be knowledgeable about the cultural background of limited

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English proficient students and attempt to integrate that culture into the classroom.

Snow (1990) outlines various techniques that immersion teachers can use to facilitate content and language learning. These include: use of body language, predictability in instructional routines, drawing on background knowledge to aid comprehension, use of realia, visuals, and manipulatives, review of previously covered material, building redundancy into the lessons, explicit teacher modeling, indirect error correction, and comprehension checks. She especially emphasizes the usefulness of group work among students to foster communication as well as the importance of a cooperative, rather than competitive, classroom environment.

Chamot (1985) sees four facets of second language learning that need to be developed in content-based instruction:

1. Vocabulary and technical terms associated with the subject (e.g., math, social studies, science).

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2. Language functions needed for academic communication (e.g., informing, explaining, classifying, evaluating).
3. Language structures and discourse features associated with different academic disciplines.
4. Language skills emphasized in the classroom for different academic functions. (pp. 50-51)

It is this language development component that distinguishes content-based second language instruction from regular content instruction.

Snow, Met and Genesee (1989) propose a conceptual framework for the integration of content and second language instruction. According to their model,

> language-learning objectives in a content-based program are derived from three sources: (a) the second/foreign language curriculum, (b) the content-area curriculum, and (c) assessment of the learners' academic and communicative needs and ongoing evaluation of their developing language skills. From these sources, two types of language

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> objectives can be specified: content-obligatory language objectives and content-compatible language objectives. (p. 205)

The authors stress that in such an integrated approach the language curriculum is altered so that "language objectives and content objectives compatible with each other are taught concurrently" (p. 206). They also point out how important it is for the content and second language teacher to work together.

Snow et al. apply their model to four different school settings: (a) the mainstream class - the mainstream teacher works closely with the ESL teacher and both plan to meet the linguistic needs of the limited English proficient (LEP) students in the content class as well as in the separate ESL class; (b) the ESL class - in this setting no special accommodations are made for the LEP students in the mainstream class, but their separate ESL class explains and builds on concepts and vocabulary used in the content class; (c) the immersion class - in this situation the content teacher and the language teacher are the same; the immersion teacher has to be careful to develop content-compatible language; and (d) the

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FLES class - in this setting foreign language objectives derive from the content-compatible language of the standard school curriculum. One can add to this list the sheltered class. In this setting LEP students are placed together in content classes in which the teaching of the content (e.g., math, social sciences, etc.) is adapted to their level of linguistic proficiency. Along with sheltered content classes students also take ESL classes.

Hudelson (1989) feels the following principles are important in developing content-based language instruction:

1. Students learn both content and language by being active, by doing things, by participating in activities directly related to specific content, and by using both oral and written language to carry out these activities...
2. Students learn both content and language interacting with others as they carry out activities...
3. All of the language processes are interrelated...

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4. Students learn to read by interacting with whole, authentic texts (by reading), and they learn to write by creating whole, authentic texts (by writing)...
5. Reading comprehension is facilitated by having prior knowledge of the text... (pp. 139-140)

To summarize, integration of content and language teaching can only be successful if content-obligatory and content-compatible language are carefully developed, and if learning takes place in a communicative, supportive environment, centering around activities which relate to the students' personal experiences.

Integrating English as a Second Language and Mathematics

Due to the difficulty of the content, mathematics has traditionally not been considered a subject that could foster second language acquisition. However, in recent years educators have taken a second look at this subject area and realized some of its potential contributions to second language learning. First and

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foremost is the realization that mathematics teaches problem-solving skills, and that such skills are transferable to all other areas of learning. Furthermore, solving mathematical word problems can help students expand their vocabulary greatly. The names of any number of things, such as objects or animals, can be incorporated into word problems and in this way give students challenging opportunities to engage in meaningful practice of such new words.

Another argument in favor of integrating mathematics and English as a second or foreign language is that in discussing mathematical problems relatively basic English can be used. Mathematical terminology, or the mathematics register itself, is, however, highly specialized and complex. However, the subject-specific technical expressions will be new to native and non-native speakers alike. One has to make sure that students understand that certain common English words have different, very specific meanings when used in a mathematical context.

Many examples can be cited illustrating the difficulties LEP students have with certain common English words, especially when they are used in mathematical word problems. Jones (1982) conducted a

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study of the understanding of the relational terms "more" and "less" used in mathematical problems. He gave the same set of mathematical problems containing these terms to two different groups of Papua New Guinea children. For one group English was the native language, for the other group English was a second language. Jones found that the non-native speakers of English lagged two to four years behind the native speakers in their mastery of certain mathematical concepts containing "more" and "less."

Kessler (1987) points out that in addition to common English words which take on a different meaning in a mathematical context, certain words and contexts in mathematical word problems can be difficult to understand for LEP students, thereby making it impossible for them to solve the word problem, although they might well possess the mathematical skills to do so. She cites a word problem involving rollercoaster rides in an amusement park. The majority of the LEP Hispanic students in a sixth grade she taught were not familiar with the word "rollercoaster," nor did they know the meaning of "amusement park." This example points to the simple necessity that teachers must make special efforts to ensure that all words and contexts

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in mathematical word problems are known to LEP students.

Dawe (1983) conducted a study of bilingual children's ability to reason deductively in mathematics. He tested bilingual Punjabi, Mirpuri, Italian, and Jamaican 11-13 year old children attending schools in England and compared their results to those of a group of English monolingual students. He found that the English monolingual children performed the best on logical connectives, followed closely by those groups of bilingual children whose competence was strong in the first as well as in the second language. Clarkson and Galbraith (1992) gave several mathematics and language tests to sixth grade students from five schools in Papua New Guinea. For all students English was a second language, and English was the language of instruction in school. Clarkson and Galbraith found that students with lower competence in both their native and their second language performed less well on the various mathematics tests than students with strong competence in both languages. Dawe's and Clarkson and Galbraith's studies lend support to Cummins' lower Threshold Hypothesis discussed earlier in this paper. Cognitive development appears to depend in part on

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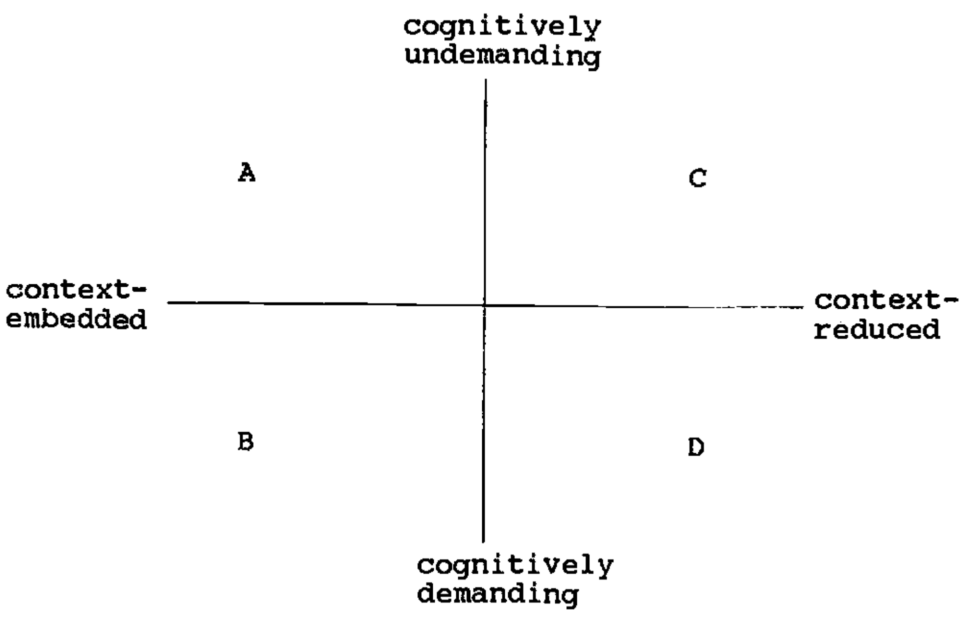
adequately developed first language skills. One can conclude from these studies that LEP students' mathematics as well as English language skills would develop best if the students were to continue receiving some instruction in their native language.

The language of mathematics relates very closely to CALP, discussed earlier in this paper. It is a context-reduced language which is communicated by signs, symbols, formulas and equations. Cummins developed the following diagram showing the range of contextual support and degree of cognitive involvement in communicative activities (see Cummins & Swain, 1986, p. 153):



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Curtain and Pesola (1988, pp. 99-100) give two examples of where certain mathematics activities would fall in Cummins's model: Mathematics computations would be located in quadrant B (context-embedded and cognitively demanding), and mathematical word problems without illustrations would be found in quadrant D (context-reduced and cognitively demanding).

The language of mathematics requires, to use Cummins's terminology, CALP (rather than BICS). It is a context-reduced language which is cognitively demanding. Kessler, Quinn and Hayes (1985) distinguish further between two different kinds of mathematical proficiencies, similar to BICS and CALP: basic individual mathematical skills (BIMS) and cognitive, analytical, mathematical proficiency (CAMP). CAMP is independent of any particular natural language. It is the ability to reason using the underlying, abstract structures of mathematics. Once developed, this ability can surface in any language.

Dale and Cuevas (1987) point out that the mathematics register includes unique vocabulary, syntax, semantic properties, and discourse features. Students have to learn mathematical symbols, specific mathematics vocabulary (such as divisor and quotient),

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and re-learn everyday English words in a mathematical context (e.g., equal, rational, table, and less). They also have to realize that one mathematical concept, such as addition, can be expressed by any of the following words: add, plus, combine, and, sum, increased by.

In the area of syntax students are confronted with expressions such as "greater/less than," "n times as much", "as...as", prepositions (8 divided by 4), and so on. Dale and Cuevas (1987) note:

> One of the principal characteristics of the syntax used in a mathematical expression is the lack of one-to-one correspondence between mathematical symbols and the words they represent. For example, if the expression "eight divided by 2" is translated word-for-word in the order in which it is written, the resulting mathematical expression $8\overline{)\,2}$ would be incorrect. The correct expression is $2\overline{)\,8}$. (p. 15)

Logical connectors, such as "if...then", "if and only if", "because", "that is", "for example", "such that",

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"but", "consequently", and "either" also present problems to students.

Furthermore, the algorithms and notations used to solve certain mathematical computations (for example, division) are different in various cultures. Teachers must be aware of this fact and show LEP students who are used to different algorithms and notations the connection between the old and new way of solving the same type of mathematical problem.

When translating word problems into mathematical equations, students have to identify correct semantic references, something that is difficult for native speakers, but even more so for LEP students.

At the discourse level, Bye (1975) notes that mathematics texts lack redundancy and paraphrases, are conceptually packed, are of high density, require up-and-down and left-to-right eye movements, require a slower reading rate than natural language texts, require multiple readings, use a variety of symbols such as charts and graphs, and contain a large number of technical words with precise meanings. LEP students would thus seem to need special help with mastering the mathematics register.

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Mathematics and English as a second language can be integrated in two ways: "(a) incorporating mathematics content into ESL instruction, and (b) incorporating English teaching strategies into mathematics instruction" (Dale & Cuevas, 1987, p. 11). In both cases, the mathematical and language skills to be learned have to be analyzed.

Cuevas (1984) proposes an instructional model for dealing with English as a second language in the mathematics classroom. The approach is composed of two strands, one focusing on mathematics content, the other on language skills (mathematics specific language skills and related language skills). The mathematics and language skills needed are analyzed and diagnosed. The teacher then implements appropriate preventive and prescriptive activities. Dale and Cuevas (1987, p. 37) summarize this approach: "Teachers must analyze each mathematical task into mathematics and language skills. Instructional activities that integrate both kinds of skills must then be devised for the prescriptive and evaluation phases of the approach."

Secada and Carey (1990) outline two approaches to teaching mathematics to LEP students which they have found to be very effective. Active Mathematics

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Teaching (AMT) can convey large amounts of basic information, and Cognitively Guided Instruction (CGI) is suitable for developing problem-solving skills and higher-order thinking.

AMT is highly structured and prescribes that out of a 45-minute mathematics lesson, 8-10 minutes be spent on review, 20-25 minutes on developing new content, and, at most, 10-15 minutes on individualized seatwork. Homework is assigned to supplement seatwork.

CGI is anchored in four principles: (a) teachers should know how specific mathematical context is organized in children's minds; (b) problem solving should be the focus of instruction; (c) students should be encouraged to say what they think about the context in question; and (d) teachers should make instructional decisions based on their knowledge of their students' thinking processes. The CGI approach appears to have great potential for language development, as it aims to actively involve students in solving mathematical problems.

Dawe (1986) describes a useful approach to teaching mathematics in a multicultural setting which is somewhat similar to CGI:

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1. Children experiment with a suitable structured activity.
2. They record and analyze the results looking for interesting patterns and relationships.
3. Opportunity to talk about their work is given.
4. Mathematical ideas are perceived and (using learner language) are expressed as discoveries.
5. These will be re-applied to make further investigations. (p. 9)

The mathematics curriculum at the elementary level is usually composed of the following four basic areas: concepts, computation, applications, and problem-solving. The computations of adding, subtracting, multiplying, and dividing are central in the early years. However, many other concepts, such as shapes, time, and graphs are also taught during the elementary years. Dale and Cuevas (1987) note that at the elementary level ESL and mathematics learning should be based on students' real-life experiences and provide situations in which the students can interact with the teacher and other students. They feel that a classroom

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environment organized around interactive activities promotes mathematics and English learning. Reilly (1988) stresses the use of graphics, manipulatives, and other hands-on experiences when introducing new concepts. This will make the meaning of new vocabulary and concepts much clearer to limited English proficient students. Cantoni-Harvey (1987) feels that it is extremely important that mathematics instruction at the elementary level be predominantly activity centered. Classroom activities will then provide a rich environment for learning language. And Cortez (1983) has the following suggestions for adapting content area lessons for inclusion into the elementary school ESL curriculum:

1. Identify the key words in the lesson. (Many teacher's editions include the key words in the behavioral objectives).
2. Summarize the key concepts.
3. Prepare several relevant sentences in keeping with the students' level of English proficiency.

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4. Prepare and/or adapt appropriate comprehension questions concerning the gist of the lesson.

On the basis of an analysis of the research on bilingualism and mathematics, Lass (1988) developed an excellent list of guidelines for improving mathematics instruction for bilinguals which highlight some of the points that have been made in this paper. Her list includes the following recommendations:

1. Develop bilingual students' first-language (L1) competence, especially to improve later mathematical ability in English.
2. Develop bilingual students' second language (L2) proficiency.
3. Recognize that mathematics is not necessarily a "universal language" for bilinguals.
4. Teach mathematics vocabulary directly and systematically.
5. Consider pairing L2-dominant students with L1-dominant students for English mathematics instruction as one grouping method.

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6. Recognize the positive effects of bilingualism on mathematics learning. (p. 481)

To summarize, integrating mathematics and English as a second language at the elementary level can be successful if special attention is paid to developing mathematical as well as related language. Teachers need to keep in mind that the language of mathematics is a context-reduced language which is cognitively challenging. Meaningful context in the form of relevant activities must therefore be provided.

Integrated English as a Second Language and Mathematics Activities for Grades 1-4

An activity-centered, problem-solving approach has been found to be most beneficial when integrating English as a second language and mathematics instruction. Chamot and O'Malley (1988) have developed an excellent mathematics textbook specifically for elementary limited English proficient students. The book uses pictures to develop vocabulary and contains activities that develop problem solving skills and foster communication. According to Krulik and Rudnick

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(1988), mathematical problem solving usually consists of five steps: (a) reading or understanding the problem; (b) exploring possible strategies for solving the problem; (c) selecting a strategy; (d) solving the problem; (e) checking the solution and taking a different approach if the solution is not satisfactory.

Chamot and O'Malley's textbook is an exception. Most of the mathematics textbooks on the market today do not specifically address the needs of LEP students, although some offer advice on how to accommodate these students. Textbooks can be adapted or complemented. Activities listed in them can be changed so that a communicative experience is provided. Mathematics practice sheets, which, in the elementary grades, often include pictures or drawings of objects, animals, or people can be furnished with the English words for these objects. New mathematical concepts and vocabulary can be introduced by reading appropriate books (fiction or non-fiction) to the class. (For suggestions for such reading, see Thiessen and Matthias, 1992.)

In the following pages eight examples of integrated mathematics/ESL activities are outlined. They have been selected with a view of promoting

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communicative language interchange in classroom settings. It is thought that the types of activities described will foster mathematics as well as second language learning.

The textbook series Addison-Wesley Mathematics has been consulted to determine appropriate grade levels for each activity described. For each activity mathematics as well as language objectives are indicated. Related literature (fiction or non-fiction) listed with each activity is meant to be used either as readiness or follow-up activity. The activities described below can be used either in mathematics instruction which emphasizes English language development, in ESL classrooms, or as enrichment activities in FLES programs.

Activity 1: Shapes, Focussing on the Square

This activity is adapted from Cantoni-Harvey (1987, pp. 132-134).

Grade Level: 1

Related Literature: Hoban, T. (1986). Shapes, shapes, shapes. New York: Greenwillow.

Mathematics Objectives: To introduce various geometrical shapes, emphasizing the square. To

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introduce the concept of a set. To learn to distinguish between the various geometrical shapes.

Language Objectives: To introduce the words square, triangle, circle, rectangle, shape, set. Language used: "This is a square." "This is not a square." "It is a rectangle," and so on. "Does this shape belong to the set of squares?"

Related Language: "This square is red, blue, ..." (colors); "This square is bigger/smaller than that square" (size comparison).

Materials Needed: Colored construction paper to cut out a variety of flat geometric shapes (squares, triangles, circles, rectangles) of various sizes and colors. Feltboard.

Procedure: Divide children into groups. Provide each group with a packet of shapes. Have children scatter shapes on the rug, and encourage them to play with the shapes. Various groups will sort the shapes by different criteria (shape, color, size). Go around and join in the groups. Discuss how they are sorting the shapes. Next, have a whole-class activity in which you elicit the names of the various shapes and introduce the concept of a set. Names of shapes should be written on the blackboard. Have children attach

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various shapes on a feltboard according to your directions. As a follow-up activity, ask children to find square objects in the classroom. This activity could be repeated over a period of several weeks, each time emphasizing a different shape.

Activity 2: Time

Grade Level: 1

Related Literature: Maestro, B., & Maestro, G. (1984). Around the clock with Harriet: A book about telling time. New York: Crown.

Mathematics Objectives: To tell time on the hour and on the half hour (on mechanical and digital clocks).

Language Objectives: clock, watch, o'clock, minute hand, hour hand; It's ten o'clock; It's ten thirty.

Related Language: Vocabulary relating to daily activities, e.g., I get up at 7 o'clock; I go to school at 8 o'clock; I eat lunch at 12 o'clock, etc. Questions relating to these daily activities, e.g., When do you get up in the morning?

Materials Needed: Worksheets, self-made cardboard clocks.

Procedure: This activity presupposes that students can already tell time to the hour and half hour. Students

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had previously been given a worksheet to take home. They had been instructed to note down the time they do various daily activities (to the nearest hour or half hour). The activities were listed on the worksheet. The students have self-made cardboard clocks.

The teacher starts the lesson by telling the class when she does various daily activities, showing, if possible, pictures of these activities (e.g., I get up at 6 o'clock; I eat breakfast at 7 o'clock; I watch TV at 6:30 in the evening; I go to bed at 10 o'clock). With each sentence the teacher shows the time o ι the self-made cardboard clock. She then asks students about their daily activities and writes sample questions and answers on the board:

Peter, when do you get up in the morning?
I get up at 7.
Peter gets up at 7.
Mary, when do you usually eat dinner?
I eat dinner at 6:30.
Mary eats dinner at 6:30.

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Each student who answers is asked to show the time on his/her cardboard clock. The teacher then distributes worksheets which contain sentences like:

________ gets up at _____.

________ eats breakfast at _____.

________ goes to school at ______.

________ eats lunch at _____.

________ gets home at _____.

________ eats dinner at _____.

________ watches TV at _____.

________ goes to bed at _____.

The teacher goes through the worksheet with the students, making sure all words are known to them. Students are then instructed to work with a partner, asking each other questions and filling in the worksheet (the name of the partner and the times have to be filled in). During the pair work the teacher goes around giving help when needed. Students will report on what they found out about their partners at the beginning of the next lesson.

In first grade the mathematics curriculum covers counting (from 1 to 100), addition and subtraction

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(first up to 10, then up to 18), time and money, geometrical shapes, and measurement. These objectives lend themselves very well to language and vocabulary development. By bringing manipulative materials into the classroom (e.g., toys or pictures) students can count, add and subtract, and learn at the same time the words of the things they are counting, adding, or subtracting. Math worksheets could be done in groups rather then individually. Math worksheets at this stage display the pictures of the items to be added or subtracted. The teacher could supply the words in written form, and students could copy them onto their worksheets, next to the matching pictures. This would expand students' vocabulary greatly. It would be best if such worksheets were thematically grouped, one displaying pictures of toys, another one displaying pictures of fruit, and so on.

Activity 3: Grocery Store

This activity is adapted from Dale and Cuevas (1987, pp. 48-49).

Grade Level: 2

Related Literature: Spier, P. (1981). Food market. Garden City, NY: Doubleday.

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Mathematics Objectives: Choose and match sets of coins with values up to 99 cents; add prices up to 99 cents; compare prices with amounts of money.

Language Objectives: "This costs ...cents." "This costs as much as/less than/more than that." "You need ...quarters, ...dimes, ...nickels, ...pennies to buy this item."

Related Language: Names of items commonly found in a grocery store. This activity is intended as a follow-up. Children are already familiar with the various coins and can add them up (up to 99 cents).

Materials Needed: Empty food containers (cereal boxes, soup cans, and so on) of items usually found in a grocery store or supermarket. Plastic fruit, meat, and so on. Small toys. Other items usually found in a supermarket. Play money.

Procedure: Set up a grocery store with as many items as possible, each with a clearly marked price on it. The store should be set up as a learning center to be used by one small group at a time, while the other groups work on other problems. Groups should first have the opportunity to simply play "grocery store." They should have play coins and be able to "buy" desired items. Groups can later work on worksheets answering

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such questions as: Name one item that costs 25 cents. How many apples can you buy with 50 cents? What costs more, 3 apples or 3 oranges? What coins do you need to buy a toy car?

The grocery store game is a rich activity for developing related language. As the store is set up, the word for each item can be elicited and written on the blackboard. If the item does not contain the name on the label, a label should be made and attached to the item. The word could, for example, be written on the reverse side of the price tag. The whole class can be involved in getting items ready to be set up in the grocery store.

Activity 4: Survey of Pets

Grade Level: 2

Related Literature: Brown, M. T. (1990). *Arthur's pet business*. Boston: Joy Street Books.

Mathematics Objectives: Doing a survey; making a bar graph of data from a survey.

Language Objectives: Survey, tally, survey results, bar graph.

Related Language: Names of common pets.

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<u>Materials Needed</u>: Worksheets with blank bar graph grid and names of common pets.

<u>Procedure</u>: The teacher announces that she would like to know what kind of pets the children in her class have. First, she solicits names of common pets. She shows pictures of the various pets and writes the names on the board. She then asks the students how she could find out how many types of pets the children have. She announces she is going to do a survey. She asks children to raise their hands if they have one or more of the type of pet she calls out. She tallies the results on the board, e.g.:

Dogs	𝍸 𝍸 ||	(=12)
Cats	𝍸 ||||	(= 9)
Fish	𝍸	(= 5)
Birds	𝍸 |	(= 6)

The teacher then explains how to show these results in a bar graph and draws a bar graph on the board. The bar graph shows the types of pets and how many children own a certain type of pet. The teacher then divides the class into groups of 5 students. Groups are given a worksheets which contain the following information:

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Take a survey of the pets the children in your group own. How many children have:

Dogs

Cats

Fish

Birds

Hamsters

Mice

The children are to tally the results and color in the results on the bar graph pre-printed on the worksheet. The teacher goes from group to group helping the children. Bar graphs are posted and can later on be used for a bar graph reading activity.
In situations in which it is likely that a substantial number of children do not have pets and would teel left out, this activity can be changed to taking a survey of the colors of clothing the children are wearing.

<u>Activity 5: Monkey Math</u>

This activity is adapted from Commins (1990, pp. 128-129).

<u>Grade Level</u>: 3

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Related Literature: Carle, E. (1989). Animals, animals. New York: Philomel Books.

Mathematics Objectives: To supply missing addends or subtrahends (addition facts up to 18).

Language Objectives: Pronunciation of numbers 1 through 18. Parallel writing, in two rhyming lines.

Related Language: Names of animals. Sentences describing everyday activities.

Materials Needed: "Monkey Math" sheet.

Procedure: Distribute "Monkey Math" sheet to students. On the sheet students find rhyming sentences, such as:

> 15 little monkeys stayed up late,
> ____ went to bed and then there were 8.
> There were 6 little monkeys waiting to dine,
> ____ more joined them and then there were 9.
> There were 18 little monkeys learning to dive,
> ____ couldn't do it, which left only 5.

As the whole class works through the problems, explain any unfamiliar words. After the correct numbers have been filled in, go through the whole worksheet using it as a jazz chant (this can be done several times, with slight variations). Then divide up students into

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groups and have them write similar rhyming couplets using other animals of their choice. Move from group to group during this activity and help students find the words they are looking for. Have groups exchange problems and solve them. Re-convene as a whole class and write students' couplets on the blackboard or on a big writing pad. Again, have the class say the couplets in the form of a jazz chant. Later on, duplicate the couplets for all students and hand them out to them to keep.

Activity 6: Perimeter

Grade Level: 3

Related Literature: Yenawine, P. (1991). Shapes. New York: Museum of Modern Art/Delacorte.

Mathematics Objectives: To measure the length of the sides of shapes. To calculate the perimeter of shapes.

Language Objectives: Shape, side, length, distance, perimeter, measure, ruler, inch(es).

Related Language: Names of shapes (triangle, rectangle, square, polygon), names of colors. " How long is this side?" " This is x inches long." "This shape has the longest (shortest) perimeter." "The perimeter of this

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shape is longer (shorter) than the perimeter of that shape."

Materials Needed: Rulers, various shapes in various colors cut out of construction paper, worksheets.

Procedure: This activity presupposes that students already know how to measure length in inches with a ruler. The teacher begins the lesson by holding up a shape, e.g., a rectangle, and asks the class how to find out the distance around this shape. Students suggest measuring the length of each side and then adding up all the lengths. The teacher draws the shape on the board and has students measure the side with an inch ruler. She writes the measurements along the sides of the shape. The class then adds up the lengths. The teacher explains that this is called the perimeter of the shape or figure and writes the word on the board. She repeats this procedure with an nonsymmetrical six-sided polygon. She then divides the class into groups of four and provides each group with a pack of shapes (made out of construction paper) and a worksheet on which the outlines of the construction paper shapes are reproduced. Students are to color the shapes on the worksheet, matching the construction paper shapes. They are then to measure the length of

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the sides of each shape with a ruler, enter the measurements of the shapes on the worksheet and calculate the perimeter of each shape. During this activity the teacher visits with the groups and gives the children whatever guidance is needed. The whole class then resumes, and selected children are called upon to demonstrate on the board how they calculated the perimeter of a certain shape. The teacher concludes the lesson by comparing the perimeters of certain shapes (finding the shape with the longest/shortest perimeter; comparing the perimeter of one shape to that of another).

Activity 7: Writing Word Problems from Outlines

This activity is adapted from Dale and Cuevas (1987, pp. 51-52).

Grade Level: 4

Related Literature: Jay, M., & Hewish, M. (1982). Airports. New York: Watts.

Mathematics Objectives: To write a word problem from a word problem outline using basic multiplication and division facts; to solve a word problem using basic multiplication and division facts.

Language Objectives: Writing a basic story problem.

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Related Language: This type of activity can be adapted to any topic. It would be best to have a "theme" for each set of word problems. Vocabulary can then be developed beforehand around this theme.

As an illustration, the theme "At the Airport" is used. Vocabulary related to airports should be developed (e.g., airline, (air)plane, ticket counter, ticket, terminal, aircraft, hangar, bus, truck, passenger). Vocabulary can be introduced by using a movie, video and/or pictures about airports and air travel. Some sample word problems should be solved in the whole-class setting. Students are then divided into groups. Each group is given several word-problem outlines. They are instructed to write story problems using the outlines. Each story problem should be related to activities at an airport.

Example:

Outline

4 ticket lines

9 people in each line

How many people in all?

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Story Problem

The airport terminal is very busy. At one airline counter there are 4 ticket lines with 9 people in each line. How many people are waiting in line altogether?

During this activity the teacher should visit with each group, acting as a resource. Groups can exchange problems and solve them. Selected problems can be discussed by the whole class.

Activity 8: Planning a Valentine's Party

Grade Level: 4

Related Literature: De Paola, T. (1976). Things to make and do for Valentine's Day. New York: Watts.

Mathematics Objectives: To multiply an amount of money less than $10.00 with a one- or two-digit number. To add up amounts of money.

Language Objectives: "This costs $1.29,"and so on. "We need 5 packages of X. Each package costs Y. The total price is Z."

Related Language: Items needed for a classroom Valentine's Party: cookies, juice, candies, hearts, streamers, balloons, games, and so on. Expressions

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such as: "We need..."; "We'll need..."; "We'd like to have..."; "It would be nice to have..."; "We must have..."

Materials Needed: Worksheets, catalog pictures or realia of items needed for party.

Procedure: The teacher announces that the class will have a classroom Valentine's Party, and that the children will have to plan for it and find out how much the party will cost. The teacher asks for suggestions of items that will be needed for the party. She shows pictures or realia of the items and writes them on the board in a list, e.g., cookies, juice, candies, paper hearts, streamers, balloons. She has students guess how much each item costs and then writes the correct prices in a column next to the items. She then asks how many packages of balloons are needed, and demonstrates how the total price for the balloons can be calculated. She then divides the class into groups of four and gives each group a worksheet. The worksheet contains a party planner chart listing the items needed for the party and the unit price for each item. Groups are to decide the quantity needed of each item and to calculate the total price for each item as well as the grand total. The teacher helps groups

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during this time. When the whole class resumes groups are to give reasons why they chose a certain quantity of certain items. The groups' answers will vary, and the whole class will need to arrive at the optimal amount for each item. The quantities are then entered in the chart on the board, and total prices and the grand total are calculated. The grand total is divided by the number of students in the class to find out how much each student must contribute to the party. If that amount seems to be too high, the list will need to be negotiated.

Conclusion

The activities described above indicate that mathematics has great potential for language development, especially in the elementary grades. Hands-on, manipulative experiences foster communication. The possibilities for developing vocabulary and basic sentence patterns through word problems are virtually limitless. Mathematical problems can also easily be changed into information-gap activities. Such activities develop speaking and listening skills. Most important, mathematics develops

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problem-solving skills, and these skills can be transferred to all other areas of learning.

Integrated mathematics and ESL lessons have been used in the United States for over a decade in schools with a high percentage of limited English proficient students. Mathematics content lessons are adapted to facilitate language learning of LEP students. However, content-based language teaching has traditionally not been employed in foreign language teaching. This paper has attempted to demonstrate that selected mathematical concepts and applications can add a stimulating and challenging component to the EFL curriculum.

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